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CASUALTIES ATTRIBUTED TO TOXIC GAS
AND SMOKE AT FIRES
A SURVEY OF STATISTICS

by

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February 1975

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SUMMARY

This note surveys the statistics of fire casualties classified as having been 'overcome by gas or smoke' in the United Kingdom Fire Statistics for the years 1955-1972 inclusive. For the period covered, the proportion of all annual casualties suffering from this source of injury (both fatally and non-fatally) has increased by a factor of about three. Currently, about half the fatal casualties from all causes in fires per annum are 'overcome by gas or smoke'.

Possible reasons for this increase are discussed and, although the available statistics do not permit any causal relationships to be established, it is considered that major factors responsible are likely to have been an increase in the amounts and, perhaps, the irritancy of gas and smoke generated in fires, resulting in more persons being trapped. An examination of the proportion of casualties surviving exposure to smoke and fire gases shows no evidence of a significant change in the toxicity of fire gases.

Key words: Fire casualties, smoke, toxic gas.

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INTRODUCTION

In recent years¹ about half the annual deaths in fires in the United Kingdom have been attributed to the effects of toxic gas and smoke. This paper surveys the available statistics with the object of examining how the numbers of both fatal and non-fatal casualties attributed to toxic gas and smoke have varied with time and in relation to casualties from other causes in fires. Possible reasons for the variations are considered.

The survey is based on the annual analyses of reports of fires attended by fire brigades in the United Kingdom (Annual Tables) prepared and published by the Fire Research Station², acting as agents for the Home Office, and covers the years 1955-72 inclusive. Some of the main conclusions have been indicated briefly elsewhere³; this paper presents the survey in detail.

CLASSIFICATION OF INJURIES

Causes of death given in the fire reports are quoted from the findings of inquests and fatal accident enquiries and are classified in the annual tables as follows:

Burns and scalds

Overcome by gas or smoke

Other and undefined injuries

(The phrase 'overcome by gas or smoke' may be read as 'overcome by gas and/or smoke').

Casualties who are described in the reports as having died from 'burns and asphyxiation' or similarly are, for 1966 and later years, included in the annual tables under 'overcome by gas or smoke'; for earlier years they were included under 'burns and scalds'. A re-classification of reports in this respect for one year, 1970, showed that the proportion ascribed to 'burns and asphyxiation' was 12.4 per cent. It will be seen later that, at this level, the change of classification will not seriously have affected the main conclusions.

Except for the years 1955 and 1971, when they amounted to 20 per cent and 13 per cent respectively, the numbers of deaths in fires classified under 'Other and undefined injuries' were less than 11 per cent of the total deaths in each year.

Non-fatal casualties include all those requiring more than first-aid treatment and their injuries are classified as below where, as a guide to the distribution of the non-fatal injuries, the approximate percentage of casualties in each of the classes is given in brackets for a single year, 1969:

Burns and scalds	(57)
Bruises, cuts, abrasions	(9)
Dislocations, sprains, fractures	(3)
Overcome by gas or smoke	(12)
More than one of the above injuries	(3)
Shock	(12)
Other and undefined injuries	(5)

Casualties who suffer shock in addition to other injury are classified according to the other injury.

For the purposes of this survey only casualties 'overcome by gas or smoke' or suffering 'burns and scalds' will be listed separately; the rest will be included with 'other and undefined injuries'.

LOCATION OF CASUALTIES

From 1961 onwards in the annual tables the incidence of casualties has been related to type of occupancy. These data have been used to prepare Table 1 which shows the mean annual percentage of fatal casualties and the mean annual percentage of non-fatal casualties which occurred in the period 1961-1972 inclusive in fires in buildings of all kinds and the percentages which occurred in buildings classed as 'private dwellings' - principally residential houses (including multiple occupancies), residential flats and maisonettes.

Table 1

Proportion of casualties in buildings
(1961-1972)

Casualty location/type	Proportion per cent
IN ALL BUILDINGS	
Fatal	88.2 \pm 8.0*
Non-fatal	85.4 \pm 6.8
IN DWELLINGS	
Fatal	76.1 \pm 8.6
Non-fatal	60.6 \pm 8.0

*Twice standard deviation of annual percentages

It is evident from Table 1 that the conclusions from this survey will apply mainly to casualties in buildings - with private dwellings predominating.

CASUALTIES OVERCOME BY GAS OR SMOKE

The numbers of casualties per annum for the years 1955-72, inclusive, are listed in Table 2 in accordance with the abbreviated injury classification described above. A preliminary inspection of Table 2 shows that the numbers of both fatal and non-fatal casualties per annum 'overcome by gas or smoke' have increased by factors of about four during the period, while the total number of casualties from all injuries has increased by about 50 per cent.

In order to remove the effect of the overall increase in the numbers of casualties per annum the fatal casualties, and the total of fatal and non-fatal casualties, 'overcome by gas or smoke' are given in Fig.1 as proportions, per cent, of casualties from all causes in fires for each year. For comparison, Fig.1 includes the proportion of casualties which were fatal from causes other than 'gas or smoke' (ie 'burns and scalds', 'other and undefined').

Averaging the first five years and the last five years of the period it is found that the proportion of casualties which were fatal owing to exposure to 'gas or smoke' increased from 2.5 per cent to 7.4 per cent, ie by a factor of 3. Similarly, the total of fatal and non-fatal casualties overcome by gas or smoke increased from 7.0 per cent to 19.2 per cent of all casualties, ie by a factor of 2.7. These increases contrast with the change in the proportion of casualties in fires which were fatal owing to causes other than 'gas or smoke'; this proportion has actually decreased from 10.7 per cent to 7.4 per cent per annum averaged over initial and final periods of five years, the decrease being about 30 per cent.

Table 2

Numbers of casualties in Fires 1955-1972. United Kingdom.
Classification by injury.

Year	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
NATURE OF INJURY																		
FATAL																		
Burns and scalds	430	380	407	339	311	334	353	480	526	364	388	365	322	333	343	358	333	459
Overcome by gas or smoke	76	112	78	95	129	135	180	150	237	268	271	376	382	477	468	425	381	502
Other and undefined	127	37	22	17	47	60	39	37	55	49	44	39	75	55	50	56	108	117
TOTAL	633	529	507	451	487	529	572	667	818	681	703	780	779	865	861	839	822	1078
NON-FATAL																		
Burns and scalds	2537	2591	2263	2195	2286	2218	2211	2379	2664	2835	2679	2632	2447	2615	2905	3010	2740	3359
Overcome by gas or smoke	145	140	133	248	191	277	249	233	367	282	422	417	473	568	624	715	710	1043
Other and undefined	1062	813	783	763	831	916	1003	1096	1192	1233	1300	1383	1730	1429	1581	1475	1567	1928
TOTAL	3744	3544	3179	3206	3308	3411	3463	3708	4223	4350	4401	4432	4650	4612	5110	5200	5017	6330
ALL INJURIES	4377	4073	3686	3657	3795	3940	4035	4375	5041	5031	5104	5212	5429	5477	5971	6039	5839	7408

It may be noted that the records in Fig.1 show no obvious hiatus at 1966 which might be associated with the change in coding. This is consistent with the estimate, given earlier, that the coding change will have affected only about 12% of the fatal casualties.

DISCUSSION

It is clear that, during the 18 year period covered by this survey, there has been a highly significant increase in both the numbers and proportions of fatal and non-fatal fire casualties attributed to the effects of smoke and toxic gases; these now emerge as the major cause of death in fires.

It might be suggested that part at least of the increase in casualties attributed to smoke and toxic gas reflects an increasing efficiency in the identification and reporting of injuries in fires. However, the effect of such increasing efficiency might be expected to be greater for fatal than for non-fatal casualties - for whom treatment depends on accurate diagnosis - and, as has been seen, fatal and non-fatal casualties have shown similar increases. Casualties from other causes show no such large increases. In particular, casualties classified as suffering from shock have increased from an average of 6.3 ± 0.6 per cent of all casualties per annum for the period 1955-1959 inclusive to 9.7 ± 0.4 per cent per annum for the period 1968-1972. This increase is thus about 50 per cent and might, for these casualties especially, be indicative of the extent of any increase of efficiency in the recognition and hospitalisation of non-fatal casualties. On balance, it may perhaps be safely assumed that the effect of such increased efficiency on casualty statistics as a whole will have been relatively small.

With the above reservation, factors which might account for an increase in casualties due to smoke and toxic gas rather than to burns and scalds at fires may be summarised as increases in the amounts of smoke and gases, changes in the nature of the smoke and gases and increases in the numbers of persons involved in individual fires. Each of these possibilities will be considered in turn.

Other factors, such as a more rapid growth of fire and changes in building design or construction, may also contribute; but they might equally well increase burns casualties rather than smoke and gas casualties and they will not be pursued here.

1. Amounts of smoke and gases

Here we have the possibilities of a general increase in the amounts, or rates of production, of smoke and toxic gases and/or an increasing proportion of fires

producing especially large amounts of smoke and gas. Effectively, an increase in the amounts or rates of production of smoke and gases implies either a wider distribution of dangerous concentrations at a given time under flow conditions in a building or higher local concentrations at a given time under cumulative conditions, eg in a compartment; either result is capable of increasing the likelihood of people being trapped at a given stage of a fire.

The annual statistical tables do not provide a measure of changes in amounts of smoke and toxic gas at fires, or of the frequencies of fires producing especially large amounts of smoke and gases, independently of the numbers of associated casualties. However, fire brigade officers report an increase in smoke and noxious fumes associated specifically with the presence of plastics materials in fires in buildings⁴.

The statistics provide no evidence whatever of a causal relationship, but the increase in casualties due to smoke and toxic gas has certainly occurred in a period in which the use of plastics generally has been increasing rapidly; an increase of 15 per cent per annum was quoted in 1966 for the use in buildings⁵, ie during the period covered here. The potential hazards associated with this increase have been recognised for some time and are currently being widely studied. An outline of the work at the UK Fire Research Station has been given elsewhere³.

2. The nature of the smoke and fire gases

An increase in the intrinsic density and/or the irritancy of smoke could lead to an increase in the numbers trapped in fires and becoming casualties. In practice, the effects of such changes in smoke quality will be equivalent to changes in quantity and the remarks of the previous section apply.

Casualties from smoke and toxic gases will have been exposed to a wide range of concentrations of toxic material for a wide range of times, and fatal and non-fatal casualties will not necessarily both have been associated with the same fire exposure. Nevertheless, averaged over a large number of incidents, such as those for one year, it is reasonable to assume that the proportion of either survivors or fatalities among casualties suffering exposure to smoke and toxic gases will provide a measure which may be used to detect changes in the toxicity of the smoke and fire gases.

Figure 2 shows the proportion of survivors (ie non-fatal casualties) in the sum of fatal and non-fatal casualties for all fires each year for the period 1955-1972 inclusive. The average for the whole period is 60.7 per cent with a standard deviation of ± 5.5 . Bearing in mind the 1966 change in classification of

fatal casualties ascribed to 'burns and asphyxiation' or the like, no significance can be attached to the trend in the proportion of survivors discernable in Fig.2, ie there is no significant evidence of a change in the toxicity of smoke and fire gases during the period covered. This applies principally to the nature of the toxic agents: a change in concentrations of existing toxic agents could change the numbers of casualties overcome by gas or smoke but not necessarily the proportion of survivors.

3. Numbers of persons involved

Together with an increase in the number of fires per annum in which fatalities occur, there has been an increase in the proportion of fatal fires in which there has been more than one death. Detailed analysis⁶ of such multiple-death fires for the period 1960-1966 showed that, of the 1000 fatal casualties, 59 per cent were overcome by gas or smoke. It may be calculated further from this data that, in those of the multiple-death incidents in which none of the casualties were at the seat of the fire, the proportion 'overcome by gas or smoke' during the period was as high as 70 per cent. These proportions are considerably higher than the average of 34 per cent overcome by gas and smoke among all fatal casualties (in all locations) for the period 1960-1966 and demonstrate the extent to which gas and smoke can be the predominant cause of fatal casualties in fires where many people are exposed - especially among those remote from the seat of the fire. In recent years there have been two examples, both in institutions, with high mortalities from this cause^{7,8}.

Table 3 has been prepared to compare the increase in fatalities in multiple-death fires with the increase in fatalities due to smoke and toxic gas in the period 1960-1972. As previously, fatalities are expressed as a percentage of all casualties and mean values for these percentages, together with their standard deviations, have been calculated for the first five years and the final five years of the period.

Table 3

Increases in fatalities in multiple-death fires
and in fatalities due to smoke and gas

Proportion of all fire casualties	Mean for 1960-64 inclusive per cent	Mean for 1968-72 inclusive per cent
Fatal in multiple-death fires	2.79 ± 0.68*	3.95 ± 1.58
Fatal due to smoke and gas	4.27 ± 1.64	7.37 ± 1.76

*Twice standard deviation

The differences between the means in the table are highly significant (at 2 per cent level or better). Assuming the average value of 59 per cent for fatal casualties overcome by smoke and gas in multiple-death fires, and also that the whole of the increase in fatalities due to smoke and gas was associated with the increase in deaths in multiple-death fires, an expected increase in the mean value for the proportion of fatalities per annum due to smoke and gas in the period 1968-1972 may be estimated as $0.59 (3.95-2.79) = 0.68$. This increase is about one quarter of the observed increase of 3.1 and indicates, but does not establish, that the increase in deaths in multiple-death fires could be a minor but not unimportant component of the increase in deaths due to smoke and toxic gas.

A short term survey of fires in dwellings in selected urban areas other than London⁹ has indicated that the risk of fire occurring in multi-occupancy dwellings is about five times that in single occupancies and the chance that a fire will result in casualties is about twice as great. It is probable that the increase in multiple-death fires is due largely to a relative increase in fires in multi-occupancy dwellings but, in this context especially, there remains the important unanswered question of whether fires generally are beginning to claim more victims, both fatal and non-fatal, in a given incident owing to an increase in smoke and gas. A major gap in our knowledge here is the number of persons at risk in a given incident.

CONCLUSIONS

During the 18 years covered by this survey, 1955 to 1972 inclusive, there has been a large increase in both the absolute and relative numbers per annum of fatal and non-fatal casualties in fires who are classed as 'overcome by gas or smoke'. In particular, the proportion of all fire casualties per annum who are classed as 'overcome by gas or smoke' has increased by a factor of about 3.

Increasing efficiency in diagnosis and a mid-term change of coding may have made some contribution to the increase, but there is reason to believe that the contribution from these sources will have been relatively small.

The available statistics do not permit any causal relationships to be established but factors which are likely to have made major contributions to the increase are considered to be an increase in the amounts and, perhaps, in the irritancy of gas and smoke generated in fires, resulting in more persons being trapped.

The proportion of non-fatal casualties among those 'overcome by gas or smoke' was 60.7 ± 5.5 for the period, with no significant trend, and it is concluded from this that there is no evidence of a significant change in the toxicity of fire gases.

An increase in multiple-death fires associated with multi-occupancy dwellings may be associated to a minor extent with the increase in casualties 'overcome by gas or smoke', but whether as cause or effect cannot be decided. An earlier

analysis of multiple-death fires has shown that the proportion of fatal casualties due to 'gas or smoke' is higher for these incidents than the average for all fires - especially among casualties remote from the seat of the fire.

These conclusions apply principally to fires in buildings, with 'private dwellings' predominating.

No attempt has been made to include in this survey a detailed analysis of the causes of death or non-fatal injury classified under 'overcome by gas or smoke'. It is, of course, well known that carbon monoxide is a major toxic component of fire gases and, indeed, poisoning by carbon monoxide is frequently established as the cause of death in fires. However, the introduction of plastics into buildings admits the possibility of a wider variety of toxic products in fire gases. These products may not only be more lethal than carbon monoxide but might also produce long term damage in non-fatal casualties. Current chemical and toxicological studies³ are aimed at assessing these possibilities but could, with advantage, be accompanied by a continuing and systematic study of fire casualties.

ACKNOWLEDGMENT

The author is grateful to Mr G Ramachandran and Mr S E Chandler for helpful discussion.

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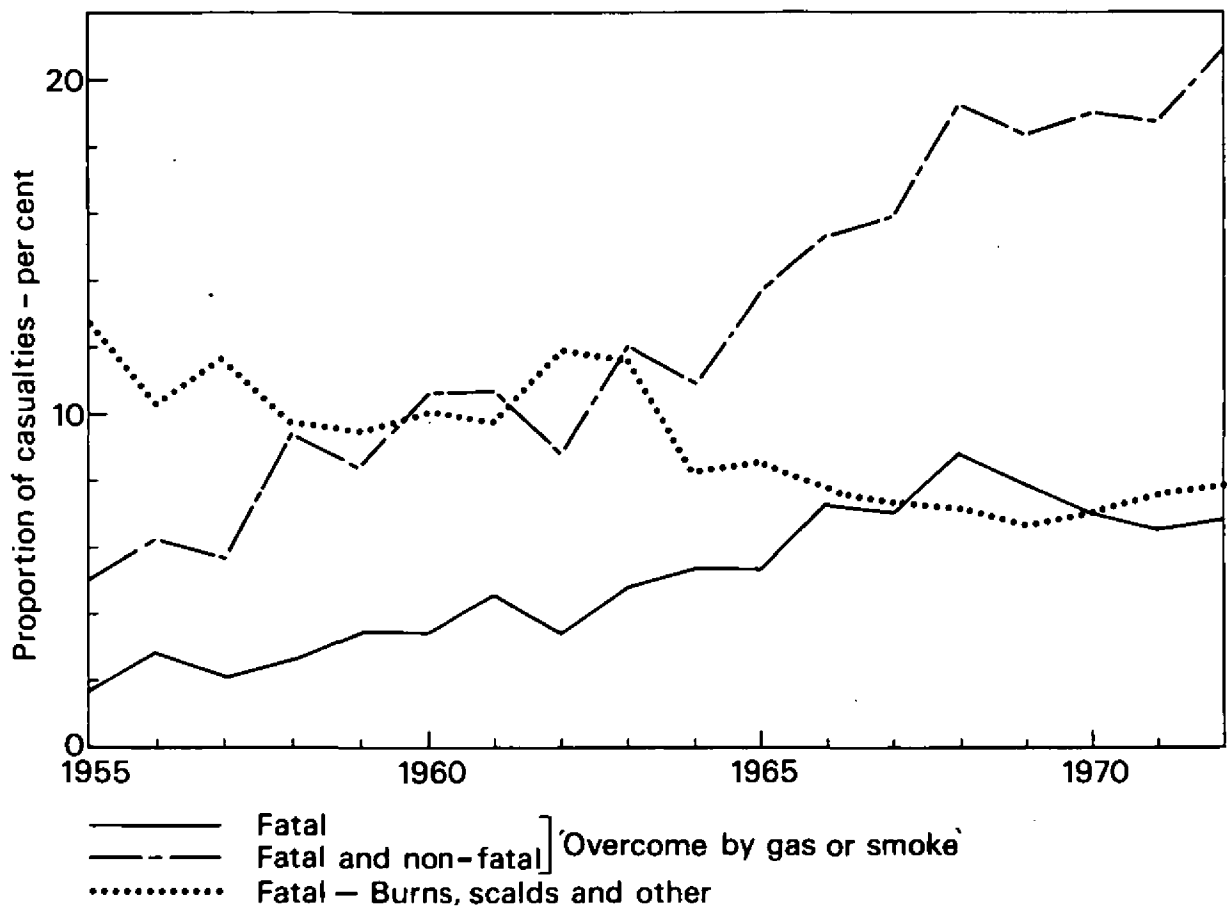


Figure 1 Casualties in fires 'overcome by gas or smoke' per annum

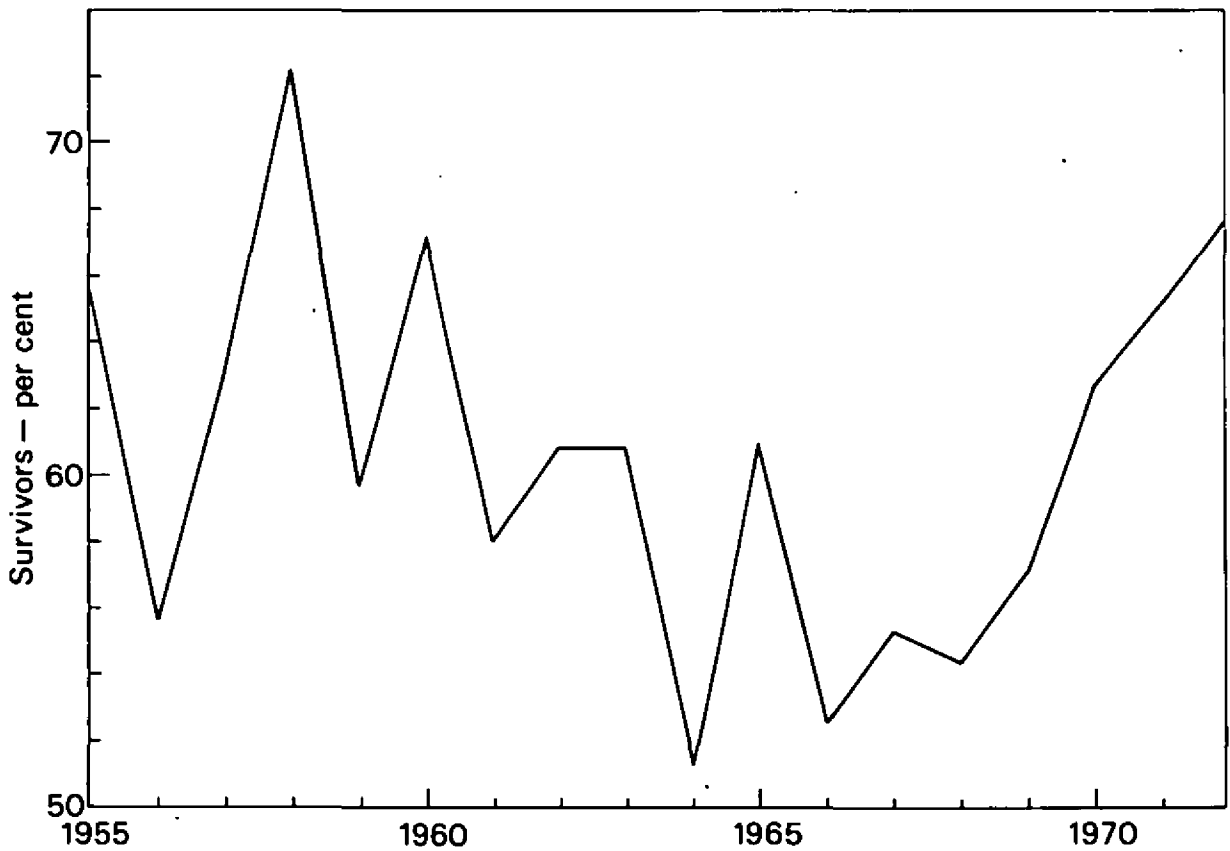


Figure 2 Survival of casualties exposed to fire gases and smoke

